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Sewage Disposal Plants for Private Houses

DECEMBER, 1909
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Engineering Experiment Station

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NO. VI

Sewage Disposal Plants for Private Houses

BY

A. MARSTON AND F. M. OKEY

DECEMBER, 1909

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SEWAGE DISPOSAL PLANTS FOR PRIVATE HOUSES

By A. Marston and F. M. Okey.

Ever since its establishment, the Engineering Experiment Station has been receiving a continuous stream of inquiries for information concerning suitable sewage disposal plants for private houses. Hence, one of the first lines of investigation undertaken by the station was the designing, construction and operation of such plants.

The work of investigation has required much more time than was at first anticipated. To secure conclusive information as to the operation of any especial plant, it has been necessary to operate it at least a year under actual working conditions. Many unexpected difficulties were encountered in connection with the development of a successful plant, and each difficulty developed by a new plant required another year of work to overcome. Hence, although our work was begun in 1904, we have not been willing to publish the results in bulletin form until now, and even yet we do not feel that our work is by any means concluded. Investigations will be continued, probably for several years to come, and the right is reserved to change our views with continued experience.

DIFFERENCE IN SEWAGE DISPOSAL CONDITIONS OF PLANTS FOR PRIVATE HOUSES AND FOR CITIES.

In attacking this problem use was naturally made of the experience of engineers in the design and operation of sewage disposal plants for cities. The first plants were designed along the same lines as the large ones required for towns, with simplified details. Early in the work, however, it became apparent that there were many difficulties peculiar to small plants as distinguished from large. The engineer who expects to secure results per unit of area in the case of sewage disposal plants for private houses equal to those obtained in the case of large sewage

disposal plants is certain to be badly disappointed. Some of the points of difference are as follows:

1. *Extreme fluctuations in flow.* The sewage of a city consists of a continuous stream of considerable volume, which, it is true, fluctuates within considerable limits, but which is very much more steady than the flow from any one of the several houses. In the case of the latter, there is a great rush of sewage when any one fixture is discharged, but during much or even most of the time there is no flow at all. In the case of the individual house, the fluctuations of flow are enormously greater in proportion to the size of the tank and area of filter beds than in the case of the city plant.

2. *Small size of sewage tank.* In the case of the city plant, the size of the tank required is so very large that the fluctuations in the rate of flow do not, if the tank is well designed, stir up the deposits and carry them out upon the filters. In the case of the individual house, however, the tank is of very small dimensions. The sudden inrush of sewage at the time of the discharge of any fixture stirs up the entire contents of the tank, disturbing the bacterial conditions and carrying out the suspended matter upon the filtering area, thereby causing it to clog. Several times the area of filter needed in city plants per person will be required in the case of the private sewage disposal plant.

3. *Fresh character of the sewage from the individual house and fluctuations in quality.* In the case of the city plant, the sewage has been carried long distances in the sewers. The suspended matter has been macerated and finely divided by mechanical agencies during the flow, and bacterial action has started in the sewers, and in many cases has proceeded so far as to effect a material change in the condition of the sewage. The mingling of the sewage from many houses gives a comparatively uniform composition, although even in the case of city plants the composition of the sewage fluctuates widely.

The sewage from the private house, however, is received directly at the plant, without mechanical maceration or division of the suspended matter, and without bacterial change. Its composition varies from solid fecal matter to pure water. Obviously, a much larger tank in proportion will be required in the

case of the private disposal plant than in the case of the city plant, in order to provide for the different conditions.

4. *Impossibility of securing proper maintenance of private sewage disposal plants.* Even in the case of a city with a plant so large that it should receive constant care, it is very difficult to secure proper maintenance. This is reported by all engineers. Most of the failures in sewage disposal plants are due to neglect of the plants on the part of the cities owning them. However, this condition is one which is capable of being remedied on the part of cities, and there is a movement for better conditions. Sanitary engineers are giving especial attention to the subject. The expensive teachings of experience are proving to the cities that they must do better in this particular.

In the case of private plants, however, it is absolutely hopeless to secure other than the most casual care of the plant. The ordinary citizen cannot be expected to possess the knowledge necessary to give scientific care to a sewage disposal plant. It is absolutely certain that he would not give it such care even if he possessed the knowledge. The private plant, to be successful, must be capable of operating at least a year with practically no attention whatever.

5. *Near proximity of private plants to dwelling houses.* In the case of the city plant, more or less odor is expected, and provision is made against its being a nuisance by constructing the plant at a considerable distance from the nearest dwelling house. In many if not most cases this would be impracticable in the case of the private plant. It must be built, often, within the confines of the same single lot on which the dwelling is placed. It must, therefore, be practically free from objectionable odor.

The authors of this bulletin have read many articles on sewage disposal plants for private houses. In these articles we have not seen proper attention given to the above differences between such plants and those for cities. If the writers of these articles would actually construct their plants and watch their operation closely under actual working conditions for a year or more it would be found that their ideas would be materially

modified by the difficulties encountered, due to the points of difference enumerated above.

THEORY OF SEWAGE PURIFICATION

To understand our reasons for the principal features of the different sewage disposal plants experimented with and the difficulties encountered in connection with each, some knowledge of the general theory of sewage purification is necessary. While there are peculiar difficulties to be overcome in the purification of sewage in private disposal plants, the general principles of purification are the same as in the case of large plants for cities.

In modern sewage purification, the process is partly mechanical and partly bacterial. While of late years most attention has been given to bacterial agencies of purification, engineers are now coming to realize that close attention must also be given to the mechanical principles involved.

In modern plants, the process of purification is nearly always divided into two parts; first, *preliminary treatment* (or tank treatment); second, *final treatment* (or filtration).

In *sewage tanks*, the aim is to separate the suspended matter in the sewage from the liquid part, and so far as possible to destroy it by bacterial agencies. The modern sewage tank is nothing but a magnified and improved cesspool. It is interesting to recall that the origin of all sewage purification methods was the private sewage disposal plant, usually, heretofore, consisting simply of a cesspool. From time immemorial, cesspools have been constructed, and we now know that bacterial agencies of purification do active work in such pools of sewage.

A sewage tank, therefore, preferably forms a part of a private as well as of a city sewage disposal plant. The bacteria working therein are principally those which can exist without the presence of oxygen. They, therefore, belong to one of the two classes, known to bacteriologists as "*anaerobic*," or those which do not require oxygen to live, and "*facultative*," or those which can live either with or without the presence of oxygen.

In a sewage tank the facultative and anaerobic bacteria use as food the organic matter which has settled out of the sewage in the form of sludge, and thereby partially destroy it. In this partial destruction, a portion of the sludge not absolutely de-

stroyed is liquefied. To a very limited extent, the bacteria in the tank also have the power of feeding upon and partially destroying organic matter in solution in the sewage.

To make the conditions most favorable for the action of the bacteria, the sewage in the tank should be entirely at rest and light and air should be excluded.

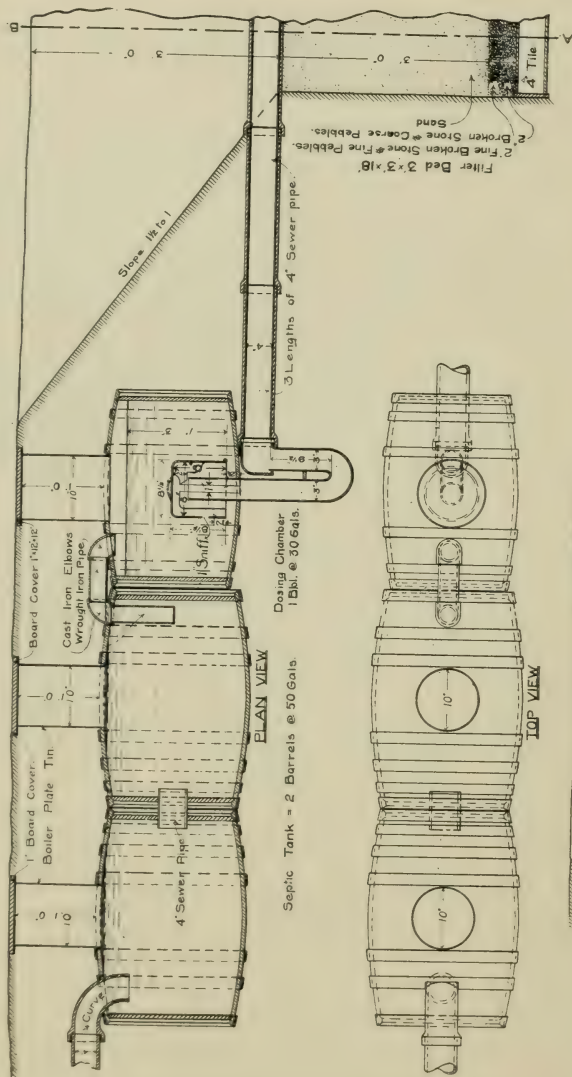
However, at the very best, the total amount of purification which can be effected by bacteria in the sewage tank is comparatively small. In city plants, the amount usually ranges from 25 to 50 per cent of purification. The effluent from such tanks is still a foul and dangerous liquid, swarming with sewage germs. It would be dangerous and cause a nuisance if discharged into tile drains or ditches without further purification.

To carry on the process of purification further, until it reaches a point which will afford a safe effluent, it is necessary to add *filtration*. In city plants, two general types of filters are in use at the present time; first *sand filters*, and second, *sprinkling filters*.

Sand filters are made of ordinary coarse, clean, mortar sand. For their satisfactory operation, the sewage must be applied to them in intermittent doses, and the surface of the sand kept in such loose and clean condition that the sewage will disappear entirely within a very short time after application of each dose of the sewage. Sand filters will not work satisfactorily when the surface is kept flooded, as under these conditions the aerobic bacteria of purification cannot exist.

In sewage filters, the purification is effected by the agency of "*aerobic*" bacteria, or those which require oxygen to live. These germs live in uncounted billions in a slimy bacterial coating covering the surface of the filter grains. In the case of sand filters, the purification germs do the most of their work at the surface of the filter.

When a sand filter is constantly kept flooded with sewage the aerobic bacteria cannot live, because they have no means of getting oxygen. By applying the sewage in intermittent doses which disappear after the application of each dose, air is drawn down into the pores of the sand as the sewage disappears and oxygen is supplied to keep the bacteria of purification alive.



PLANS OF SEWAGE DISPOSAL PLANT

FOR
PRIVATE RESIDENCE

Designed by
J. C. Gault
Checked by
J. C. Gault

FIGURE 1

EXPLANATION OF FIGURE 1.

Figure 1. shows the first private sewage disposal plant experimented with. It was constructed in 1904 and proved unsatisfactory, because of the failure of the siphon to operate properly, and because of the rapid clogging of the sand filter.

Hence, sand filters require constant care to maintain the surface in a loose and clean condition.

The other type of sewage filters, known as *sprinkling filters*, is made of coarser material than sand. Usually pebbles screened free of sand, or crushed stone are used, the size used in city plants being usually from $\frac{1}{4}$ inch to 2 inches. This coarse material has air passages throughout its extent, of sufficient size to permit the circulation of air when the sewage is trickling through, and hence the aerobic bacteria can be kept alive even when the sewage is applied continuously. However, it is necessary to have the sewage sprinkled over the surface in drops, as, otherwise, it would flow through this coarse material so quickly as hardly to come in contact with the bacteria at all, and it would fill the pores of the material so as to exclude air and destroy the bacteria of purification. In such plants, the sewage is usually sprayed over the surface from nozzles, very much as water is sprayed over the lawn in the summer time. In passing through the air, the drops of sewage are freed from objectionable gases and take up oxygen.

To recapitulate, then, the general theory of sewage purification is as follows:

In *sewage tanks* the solid matter in the sewage is allowed to settle out and is partially destroyed and liquefied by "*facultative*" and "*anaerobic*" bacteria, which also slightly affect the dissolved organic matter. The effluent from the tank is then filtered through *sewage filters*, in which "*aerobic*" bacteria carry on further the process of sewage purification. It is necessary to supply these aerobic bacteria with air. The aerobic bacteria effect a much greater degree of purification than the anaerobic and the facultative.

It may be added that the effluent of a good sand filter, properly cared for, will be as clear and odorless as spring water, and will have a very small percentage of bacteria left in it. The effluent from sprinkling filters will not be nearly so good in appearance as that of sand filters, and will have a much higher percentage of germs remaining, but if the sprinkling filters work properly, the effluent therefrom will be purified to such an extent as not to be subject to further putrefaction.

EXPERIENCE WITH EXPERIMENTAL PLANT NO. 1.

Experimental plant No. 1 is shown in Figure 1. This plant was constructed in 1904. As is shown by the figure, the sewage tank consisted of three barrels placed end to end and connected by iron pipe. The third barrel served as a dosing chamber to afford intermittent application of the sewage to the sand filter. In this third barrel was placed a 3 inch Miller sewage siphon. The operation of this siphon is such that when the dosing chamber fills to high water line the siphon will suddenly empty it. The flow from the siphon then ceases and the chamber refills.

The sand filter in this case consisted of a trench 3 ft. wide and 3 ft. deep and 18 ft. long, filled with sand and pebbles to a depth of 3 ft. overlying a 4 inch tile drain.

The use of the barrels was for the reason that this was an experimental plant only, and the cheapest temporary construction possible was considered sufficient to determine whether the plant would or would not work satisfactorily.

In operation, this plant was not found to work satisfactorily. The rushes of sewage from the house sewer thoroughly stirred up the contents of the barrels and carried out much sediment to the filter bed, which caused a quick clogging thereof. In an attempt to remedy this, the size of the filter was largely increased but without overcoming the difficulty.

Another difficulty which was not overcome was the uncertainty of action of the siphon. It was found that to insure the proper working of such a siphon would require regular examination and attention, such as could not reasonably be expected in the case of a private sewage disposal plant.

For the above reasons, the plant was considered to be a failure, in that it did not constitute a satisfactory working system for a private sewage disposal plant. However, it developed quite clearly many of the unexpected and peculiar difficulties in private disposal plants as compared with city plants, which have already been enumerated.

Plant No. 1 was designed, under the direction of one of the writers of this bulletin, by Messrs. R. J. Austin and H. J. Brunnier, seniors in the Civil Engineering Department, for their thesis. They also constructed the plant and watched its operation until their graduation a few months later.

EXPLANATION OF FIGURE 2.

Figure 2 shows the second private sewage disposal plant experimented with. The design of the tank is such as to obviate all flow through small pipes, and it was hoped that less sediment would be carried over upon the filter beds. The sand filter, too, was made much larger than in plant No. 1. This plant was constructed in 1904 and has been in continuous operation ever since. In operation, the siphon does not work satisfactorily, the sand bed soon became clogged and remains constantly flooded with sewage to a considerable depth. The wooden cover to the sand filter has decayed. The effluent is comparatively foul, but has run off in an ordinary tile drain without causing stoppage so far.

On the whole, the plant is not considered satisfactory.

EXPERIENCE WITH EXPERIMENTAL PLANT NO. 2.

After some months of experience with experimental plant No. 1, it became necessary to construct a plant to purify the sewage from the college Horticultural Cottage and Barn. In view of the experience with Plant No. 1, a design was prepared which is shown in Figure 2.

The sewage tank was circular in form, as shown in Figure 2, and was constructed entirely of brick and concrete. The dosing chamber was also circular and occupied the center of the main tank. The sewage entering was compelled to flow entirely around this circular dosing chamber before entering it. For entrance to the dosing chamber, a weir 18 inches long was provided, to reach which it was necessary for the sewage to pass under a wooden baffle-board. It was hoped by this means to prevent disturbance of the sediment in the tank and consequent early clogging of the filter beds.

The siphon provided in the dosing chamber was the same as that in Plant No. 1, i. e., a 3 inch Miller siphon. In actual operation, it was found not to work satisfactorily without comparatively frequent examination and care.

The sand filter bed was 5 ft. wide by 23 ft. long in the clear, and contained approximately twice as many square feet as in the case of Plant No. 1. This filter bed was enclosed to protect it from the weather.

In operation, it was found that the sand beds, without more regular care than could be expected for a private sewage disposal plant, would soon become clogged with sewage. This and the failure of the siphon to work satisfactorily without especial care have made this plant unsatisfactory to its designers. However, it must be admitted that it disposed of the sewage from the Horticultural Cottage and Barn satisfactorily from the date it was installed until the fall of 1909. At that time, complaint was made by the occupants of the cottage, which complaint seems to have been based more upon the decay of the wooden construction and consequent exposure of the pool of sewage over the sand filter bed than to any other cause, so far as the writers can determine.

The sewage, after passing through the filter bed, still contained considerable black material and was generally of a comparatively foul nature. Its discharge was into an existing 4 inch agricultural drain tile, and in spite of the fact that the effluent is unsatisfactory to the designers of the plant, it has run away in this 4 inch drain tile without causing stoppage or any objectionable results, which have as yet become apparent.

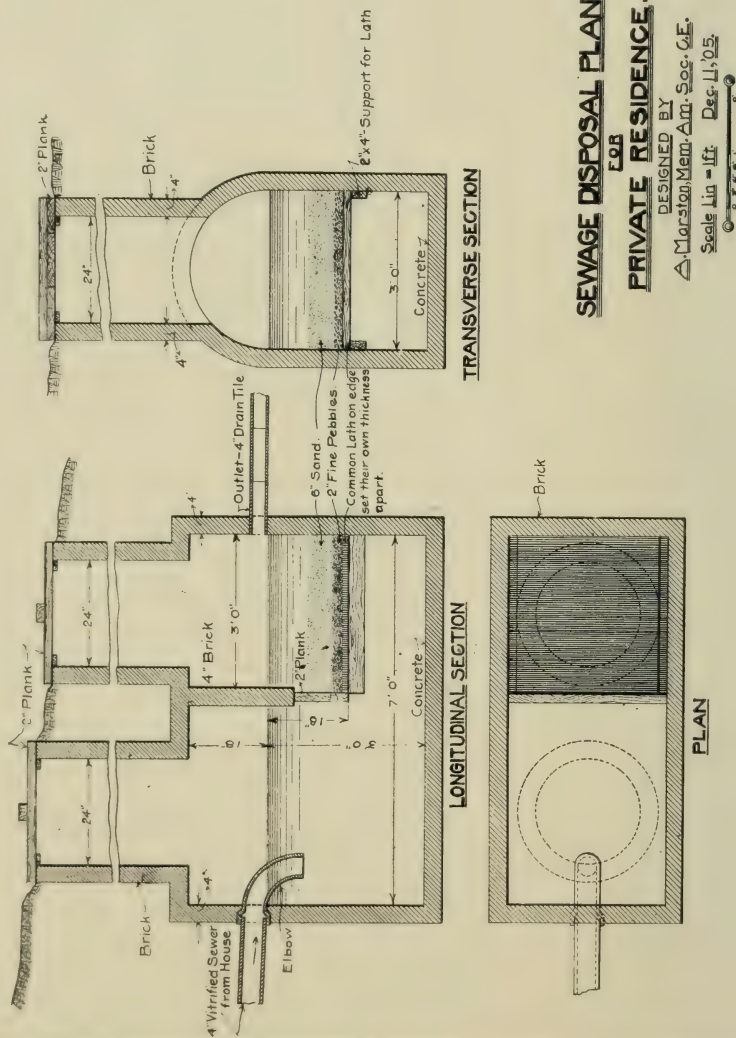


FIGURE 3

EXPLANATION OF FIGURE 3.

Figure 3 shows a form of septic tank which was designed after experience with plants No. 1 and 2, to obviate some of the difficulties encountered therewith. To prevent, as far as possible, the outflow of sediment, an upward sand filter is provided, as shown in Figure 3. In practice, this filter clogged, in some instances, at the lath grating which supported the pebbles, and the wood strips making this grating should be spaced at least 1 inch apart in the clear instead of as shown in the figure. Considerable fine, black material came out of the tank in spite of the sand filter.

Experiments are still in progress with this type of tank, and in some instances it has given as much satisfaction as could be expected of any tank without filters.

EXPLANATION OF FIGURE 3½.

Figure 3½ shows the details of a private sewage disposal plant, which, with temporary omission of cover for filter bed, was built in 1907 for the Iowa State College Central Heating Plant, and which constitutes experimental plant No. 3. The tank is built along the same lines as the one shown in Figure 3 for a dwelling, but is made larger because of the greater volume of sewage from the heating plant. A dosing chamber is added containing a 3 inch siphon, as in plants Nos. 1 and 2, and a circular sand filter 25 ft. in diameter receives the effluent from the tank.

This plant has been in satisfactory operation ever since its construction, but it receives more constant and intelligent care from the employees of the heating plant than could reasonably be expected from the ordinary private house-owner.

EXPERIENCE WITH EXPERIMENTAL PLANT NO. 3.

In view of the experience had with plants Nos. 1 and 2, which was corroborated by observation of another plant built by a private house-owner, of the same design used for plant No. 2, it was felt that a different design would be necessary for a plant which could be recommended for general private use.

Many requests for plans for private plants were constantly coming in. In view of the unsatisfactory experience with the filters, it was felt that a design for a tank alone might be desirable. The design shown in Figure 3 was accordingly prepared. In this design an attempt was made to secure a comparatively uniform and very gentle outflow by compelling the sewage to pass through an upward sand filter. This filter was supported upon fine pebbles which were in turn carried by a grating of lath on edge.

The results were considerably better than with previous designs of sewage tanks, but more sediment was carried out than had been hoped. In the course of time, there was considerable clogging at the lath grating. These facts were observed on an experimental wooden tank, built according to the same general plan. Experiments are still continuing with this type of tank, using 1 inch clear spacing of the grating bars. It is probable that where it is in use it would occasionally be necessary to remove and replace the sand filter.

No tank alone will give sufficient purification, and some means of filtration should be provided, unless discharge can be made direct into a considerable stream of water.

In 1907 it became necessary to construct a plant for the college Heating Plant, and the design shown in Figure 31½ was adopted. In construction the cover for the filler bed was temporarily omitted. This plant is larger than would be required for a single family. In operation, it is reported quite satisfactory by the men in charge of the plant. No objectionable odor is noticed from it, although it is quite close to the building. The filter bed is often found flooded, owing, it is thought, to backwater covering the outlet. Flooding of the filter should not occur with free outlet of sewage and with regular care of the sand filter. Such care would consist of loosening up the sur-

face every month or so during the summer, and occasionally removing some dirty material.

This plant receives more intelligent care than could ordinarily be expected for the private sewage disposal plant. Hence, we do not feel justified in recommending this type of plant for the ordinary private house. We should expect that it would be neglected, that the sand bed would be constantly flooded with sewage, and that the siphon would fail to operate as intended.

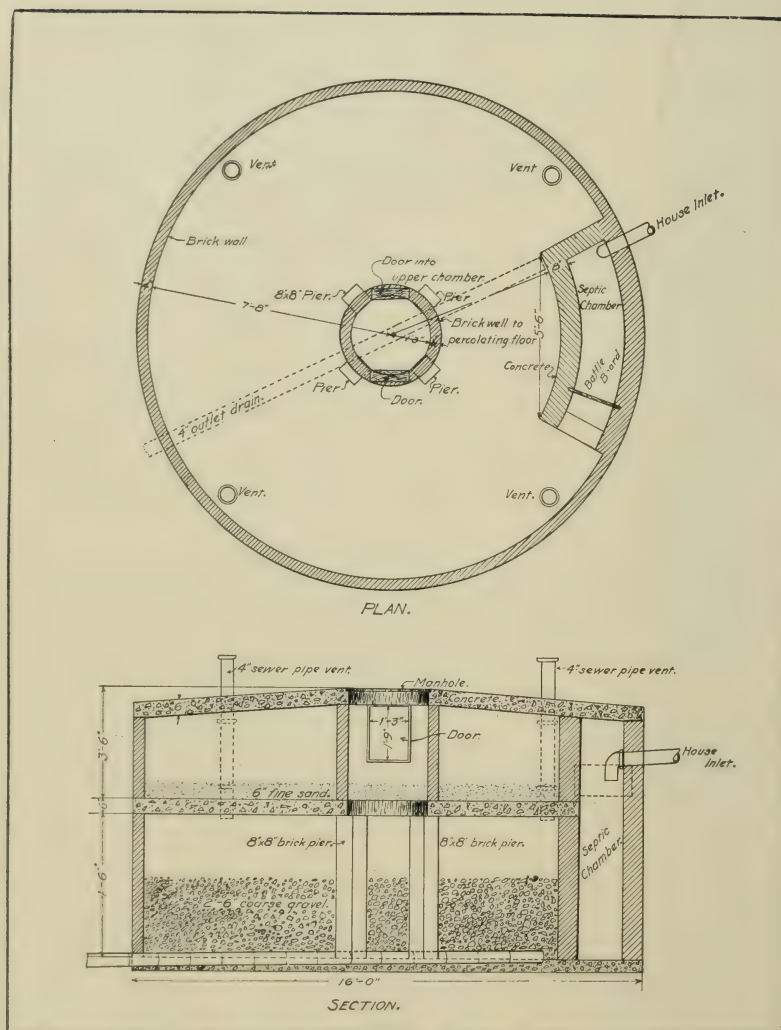


FIGURE 4

EXPLANATION OF FIGURE 4.

Figure 4 shows the most satisfactory private sewage disposal plant among those experimented with. It was constructed in 1905. It has operated for three years without any expense or care. It seems to be larger than would be needed for a single family, and would be costly to build.

EXPERIENCE WITH EXPERIMENTAL PLANT NO. 4.

Experimentation was begun in 1905 with the private sewage disposal plant shown in Figure 4. It was constructed on the principle of the sprinkling filter. This plant was built at the house of the college custodian, Iowa State College, Ames, Iowa. In constructing it the workmen put unscreened sand in the bottom filter instead of screened pebbles, as intended, and after a lapse of about one year the sand was removed and replaced with pebbles as at first intended. At this time, the cesspool tank was cleaned out. Otherwise, the plant has not needed any work or expense since its first construction. It has received the sewage of a family of six or eight people, and while not giving a perfectly clear effluent, has purified the sewage to such an extent that it has been discharged on a hillside below the plant for four years without creating a nuisance. At the present time, there is, perhaps, a wheelbarrow load of deposit of the color of lampblack in the little ditch forming the outlet, but this does not seem to cause offensive odor. So far, no especial arrangement has been made to supply a circulation of air throughout the plant, but it is believed that the work of the plant could be materially improved by providing for such air circulation.

As shown in Figure 4, the plant consists, first, of a cesspool tank in which the sewage is received from the house. Second, a sand filter 6 inches thick receives the outflow from the tank. This filter is supported by a perforated reinforced concrete floor, the perforations being of conical shape and filled with pebbles fine enough to hold up the sand. Third, there is a sprinkling filter 2 ft. 6 inches deep at the bottom, composed of pebbles having the sand all screened out.

In the operation of the plant, the sewage covers the upper filter to a depth of a few inches, and continually drops through the upper filter upon the surface of the sprinkling filter below.

TESTS OF EFFICIENCY OF CESS POOLS AND OF EXPERIMENTAL PRIVATE SEWAGE DISPOSAL PLANTS

Tests of efficiency of the plants which have been described were made by Messrs. J. B. Neely and S. R. Green in connection with their thesis investigation in 1907. Messrs. Neely and Green collected the samples. The chemical analyses were made in the laboratory of the Engineering Experiment Station, by Mr. C. E. Ellis. The bacterial analyses were made in the college Bacteriological Department.

In making the tests, it was found very difficult to secure representative samples of the raw sewage. It is believed that this was accomplished by collecting for a time the entire flow of raw sewage in a galvanized iron bushel measure. When this was filled, the contents were stirred and the sample taken. Without some such precaution as this, the sample of raw sewage would have been found to range in quality from pure water to extremely strong sewage.

The bacterial results show in each case the average of 16 separate culutre plates, two of which were poured at each of the following hours: 3 A. M., 6 A. M., 9 A. M., 12 noon, 3 P. M., 6 P. M., 9 P. M. and 12 midnight. The medium used was Agar-Agar, and the counts were made at 48 hours, the standard temperature being 28° C. The results of these chemical and bacterial analyses appear in the table on page 30.

The results for plant No. 2 in this table show the bad effects of continuous flooding of the sand filters. The same is true of the second test in the table, which was made on an experimental wooden tank similar to that in Figure 3 in combination with a sand filter like that in Figure 2.

The third test in the table shows what can be expected from a sewage tank alone, like that in Figure 3. In general, the effluent from such a tank is not sufficiently pure, and requires filtration.

The tests of plant No. 4 give, on the whole, the best results.

The tests of the private cesspools show that their effluents are swarming with bacteria and are extremely foul and impure liquids.

For comparison with the tests of private plants and cess-

CHEMICAL AND BACTERIAL TESTS OF PRIVATE SEWAGE DISPOSAL PLANTS AND CESSPOOLS

DESCRIPTION OF PLANT	Character of Sample	Chlorine	PARTS PER MILLION						Bacteria per CC.
			Albuminoid Ammonia	Free Ammonia	Nitrites	Nitrates	Oxy. Gen. Consumed	Loss on Ignition	
Plant No. 2 (See Fig. 2)	Raw Sewage	54	7.5	10.5	....	....	55.0	476	278,000
	Tank Effluent	98	7.5	48.5	....	....	90.1	670	132,000
	Final Effluent	98	42.5	10.0	high	....	71.7	484	367,000
Tank like Fig. 3, Filter like Fig. 2	Raw Sewage	100	16.0	35.0	0	0	147.1	1220	215,000
	Tank Effluent	100	7.0	40.5	....	....	125.1	836	154,000
	Final Effluent	86	2.0	28.5	....	....	86.7	368	58,000
Tank in Fig. 3	Raw Sewage	100	35.0	113.5	....	....	140.0	2056	172,000
	Tank Effluent	100	3.5	92.5	....	....	54.5	410	92,000
Plant No. 4 (See Fig. 4)	Raw Sewage	78	3.0	32.5	....	....	58.7	330	198,000
	Tank Effluent	72	1.5	36.0	....	....	47.5	240	126,000
	Final Effluent	74	1.0	19.0	high	1.3	20.5	170	24,000
Private Cesspool No. 1	Effluent	80	15.0	57.5	....	....	71.7	664	1,200,000
Private Cesspool No. 2	Effluent	132	11.0	117.0	....	....	63.4	450	930,000
Ames City Plant—Septic Tank and Sand Filters	Raw Sewage	61	7.5	20.0	0	0	96.0	230	470,000
	Tank Effluent	60	5.0	21.0	0	0	99.6	226	845,000
	Filter Effluent	80	0.6	0.1	....	4.8	20.2	250	900

pools, an analysis of a city plant in good working order is given in the table on page 30. Comparing it with the other tests, we find a much higher degree of purification in the city plant. In the private plants the nitrates show that no nitrification was effected, except in the case of plant No. 4.

SUMMARY OF CONCLUSIONS FROM EXPERIENCE WITH EXPERIMENTAL PRIVATE SEWAGE DISPOSAL PLANTS.

Our experience with the four types of private disposal plants already described leads us to the following general conclusions concerning sewage disposal plants for private houses:

1. *Size of tank.* The size of sewage tank for the private house should be much larger per person than in the case of city plants, on account of the extremely fresh character of the sewage in the former case, and its widely fluctuating quality and rate of flow.

2. *Prevention of disturbing effect of inflow into the tank.* It is especially necessary, in the case of private sewage disposal plants, that there should be provided some device for completely destroying the entering current of sewage, which, otherwise, stirs up the entire contents of the tank, owing to its small dimensions, and disturbs the purifying agencies.

3. *Prevention of disturbing effect of outflow from the tank.* Similarly, owing to the small dimensions of the private tank, it is necessary to use some special device for taking away the outflow without creating perceptible currents, as such currents will carry away sediment which will clog the filter beds.

4. *Use of mechanical apparatus not allowable in private plants.* We find that the use of any mechanical appliances, such as siphons or other automatic devices, is not permissible in the case of private plants, as all such devices require more or less attention to insure their proper working, and are almost certain not to receive such attention from the average householder. When out of order, they are fatal to the satisfactory operation of the plant.

5. *Area of filters.* Private plants require several times the area of filter per person needed for city plants because of the lack of corresponding care, and because of the extra amount of sediment carried from the tank in spite of all possible precautions.

6. *Care of plant.* No matter what the design, the householder must give some care to the sewage disposal plant. With the design which will be recommended, it is believed that such care will be confined to overhauling and cleaning once per year.

7. *Purity of effluent.* So far, it has proven impracticable to secure an effluent equal to the high degree of purity obtained from the city intermittent sand filter plants, but the effluent from the plant recommended should be sufficiently purified to prevent further offensive putrefaction.

DESIGN RECOMMENDED BY THE IOWA STATE COLLEGE ENGINEERING
EXPERIMENT STATION FOR SEWAGE DISPOSAL PLANTS
FOR PRIVATE HOUSES.

As the result of our experimental work extending over a period of five years, we have prepared the design shown in Figure 5 as embodying our present ideas. We recommend this design, but with the caution that no actual plants of the exact details shown have as yet been constructed. We hope and expect to be able to make advantageous modifications of this design from the results of our further work. We ask detailed information from those who build plants according to this design, stating the cost of construction and their experience with the working of the plants. We will warmly welcome intelligent criticism. Hence we ask for full records of unfavorable as well as favorable experience with the plants.

Vane. ← Ventilator.

Section.
Scale: = 2'

Sedimentation basin:

Technical drawing of a tapered shaft. The left view shows a tapered cylinder with a diameter of 3/8" at the top and 1/2" at the bottom. The right view shows a cross-section of the shaft with a diameter of 1/2" and a length of 1/4".

Detail of
Scale: 

Distance M to N = 6'-3 1/2"
Distance X to Y = 2'-9 1/2"
Measured on circle.

20"
Vane of #16 G. Iron
Piece of double
strength glass

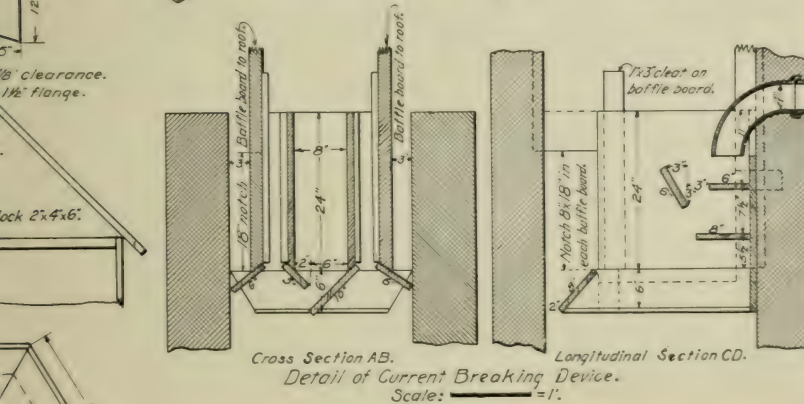
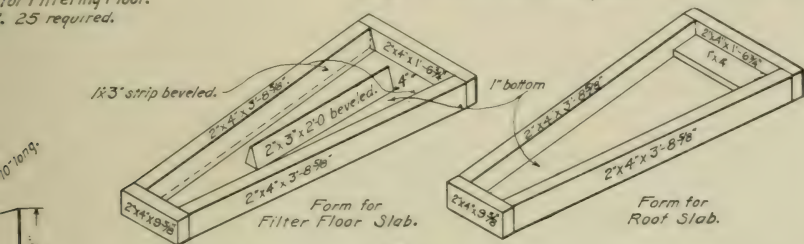
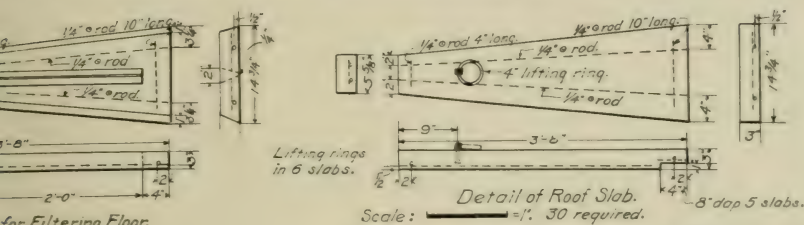
2x2" strip beveled

Wire stays
4 sides.

2x4" cross brace.

Secti

Detail of Ve
Scale: —



RECOMMENDED DESIGN
FOR
PRIVATE SEWAGE DISPOSAL PLANT

PLAN NO.5

Scales: As shown.

Engineering Experiment Station
Iowa State College, Ames, Iowa. Jan 1910.

F.M.O.

No. 28-8-A.

DESCRIPTION OF FIGURE 5.

Figure 5 shows the design of private sewage disposal plant recommended by the Iowa State College Engineering Experiment Station as embodying the best ideas obtained by five years of experimental work on such plants.

The plant consists of a cesspool chamber, a two-story filter, (the upper filter being sand and the lower pebbles) and, finally, of a sedimentation basin. The whole is enclosed in a brick masonry well, 12 ft. in diameter by 7 ft. deep, with a wooden ventilator reaching about 5 ft. above the surface of the ground. No plant of the exact description of the plant shown has as yet been built and tried out. Farmers should be able to build the plant for about \$100, in addition to their own work.

Further results of our experimental work may lead to improvements in this design.

DETAILED DESCRIPTION OF DESIGN RECOMMENDED.

The design recommended is shown in Figure 5. It consists of an *outer well*, of brick, 12 ft. in diameter outside, and an *inner well*, also of brick, 4 ft. in diameter inside. A *sedimentation basin* is added at the bottom of the inner well, and a *ventilator* at its top. One sixth of the outer well is partitioned off to serve as a *cesspool chamber*.

Outer and Inner Wells. The brick wall of the outer well is 5 ft. 10 in. in depth, and is 4 inches in thickness, except for 1-6 of the circumference which is 8 inches thick. The brick wall of the inner well is 7 ft. 11 in. deep, its top being 5 inches higher and its bottom 1 ft. 8 in. lower than the corresponding parts of the outside wall. The wall of the inner well is 8 inches thick. These brick walls and all other brick work about the plant must be laid up in cement mortar, composed of 1 part Portland cement to 3 parts of good, clean, coarse sand. No lime whatever must be permitted about the plant. The bottom of each well is composed of 3 in. of concrete, which must be mixed in the proportion of 1 part cement, to 2 parts of sand, and 3 parts of broken stone or of pebbles not containing sand. It can be made, if desired, of 1 part of cement, to 4 parts of clean gravel containing a considerable proportion of pebbles.

Sedimentation Basin and Outlet Pipe. The inner well extends 1 ft. 6 in. deeper than the outer well, and forms a sedimentation basin.

The outlet from this sedimentation basin, and from the entire sewage disposal plant, is provided by a 4 inch tile drain, laid with its inner end 1 ft. 6 in. above the bottom of the inner well. This outlet should be extended to the place of final discharge, into some ditch or on a hillside. Just above this outlet tile, two 2 in. x 12 in. plank must be laid across the inner well, supported on projecting brick at each end, so as to form a platform above the water in the sedimentation basin, on which to stand when examining the plant or working with it from the inner well.

Lower Filter. The floor of the outer well has a slope of 2 inches toward the inner well. Radiating out from the inner well are laid 18 straight lines of 4 inch tile, spaced 18 inches at the outside. The pieces of tile must be laid $\frac{3}{4}$ inch apart at the

joints, and the upper halves of the joints must be covered with broken tile to prevent the entrance of filter pebbles into the tile. The outlets for these tile are provided by omitting every other half brick from the wall of the inner well. The tile serve partly to afford a supply of air to the under part of the lower filter, and partly as outlets for the filtered sewage.

The lower filter occupies the lowest 3 ft. of the outer well, and must be composed of fine broken stone with no dust, or of pebbles with all the sand screened out. In either case, the range of size must be from not less than 1-6 inch up to not more than 1 inch in any dimension. In case pebbles are used, a screen having 1-6 inch mesh can be used to screen out the sand, and all the coarse pebbles in the pile can be broken up with a sledge or hammer. About 8 cubic yards of this material will be required for the lower filter.

Space between lower and upper filters. Beginning 1 inch above the upper surface of this lower filter, six rectangular openings, each 12 inches high by 16 inches wide, are provided in the wall of the inner well. This is to permit free access to the lower filter to examine it and introduce or take out filtering material. They also permit the free passage of air from the ventilator through the space between the lower and upper filters and out through the five vents placed around the outside of the outer well, as shown in Figure 5.

Vents. Each of these vents consists of a 2 ft. length of 4 inch vitrified sewer pipe, attached to a 4 inch vitrified elbow, passing through the outer wall in the position shown in Figure 5. The 4 inch sewer pipe are each attached to the outer wall by 2 wire loops.

The upper ends of the vents must be stopped by pieces of wire screen, to prevent objects being thrown down the vents, while permitting the free escape of air.

Floor of upper filter. The floor of the upper filter consists of reinforced concrete slabs, of the dimensions and other details shown in the separate plan in Figure 5. These slabs are 3 inches thick, and each is reinforced by 2 iron or steel rods $\frac{1}{4}$ inch round by 3 ft. 8 in. long, placed $1\frac{1}{2}$ inch from the bottom of the slab, together with 2 small cross rods, as shown in Figure 5. The edges of each slab are beveled, as shown in Figure 5, and

there is a beveled slot 2 ft. long, also as shown in Figure 5. The object of these slots and beveled edges is to permit the passage of the sewage from the upper filter. The beveled slots are to be filled with small pebbles, sufficiently fine to hold up the sand forming the upper filter. These pebbles should not be more than $\frac{1}{8}$ to $\frac{1}{2}$ inch in diameter, and in the upper portion should not be larger than $\frac{1}{8}$ inch in diameter.

Water must be turned upon the surface of the sand in the upper filter during construction, to test it and make sure that the sand does not wash out through any of the slots, and should this occur, finer pebbles must be used and the sand then replaced. This test must be continued until it is certain that the upper filter is perfectly supported, so as not to be in danger of washing out.

The floor slabs are to be constructed in molds, plans for which are shown in Figure 5. The slabs must be made of 1 part Portland cement, to 2 parts sand, and 3 parts broken stone or small pebbles with the sand all screened out; or, if preferred, they may be made of Portland cement and gravel, in the proportion of 1 part of cement, to 4 parts of gravel containing a considerable proportion of pebbles. By molding these at the surface of the ground, we avoid the necessity of wooden forms or centering to hold the floor during construction.

Upper filter. The upper filter consists of 4 inches of coarse, clean sand. About one good load is required for the filter. The walls of the upper filter must be plastered with 1 to 2 Portland cement mortar, as shown in Figure 5.

After the plant has been in use for some time, the sewage will entirely cover the surface of this upper filter and finally reach a considerable depth. Under these circumstances, the sewage will filter through the upper filter and pass down through the slots in the supporting floor and fall upon the surface of the lower filter in the form of separate drops. These drops will be exposed to the air as they fall and take up oxygen from it. In this way, a supply of oxygen for the lower filter will be maintained.

This upper filter will, in course of time, become so clogged with the sewage that the sewage will reach the height of the outer wall. When this occurs, a sufficient amount of the roof

should be lifted off to permit the sand of the upper filter to be taken out and replaced with new sand. Only about one load will be required. It is not certain how often this removal will need to be made, but it will probably be not oftener than once in two years.

Roof. The roof of the outer wall is also made of concrete slabs of the same dimensions as those of the floor of the upper filter, which are to be made in molds in the same way. Plans for the roof slabs and molds are shown in Figure 5. Like the slabs in the filter floor, each must be made in the proportion of 1 part Portland cement, to 2 parts sand, to 3 parts of fine broken stone or pebbles free from all sand; or, if preferred, they may be made from clean gravel, in the proportion of 1 part of cement, to 4 parts of good gravel containing a considerable proportion of pebbles. The roof slabs differ from the filter floor slabs in that they are not beveled, and that they are notched at one end so as to be held in place by the outer wall. They are reinforced by $\frac{1}{4}$ inch round rods just as in the case of the filter floor slabs.

All the roof slabs are removable, and one in every six is to be provided with a lifting ring at the small end. This lifting ring can readily be made of twisted wire.

Cesspool chamber. The sewage entering the tank is first received in a cesspool chamber, as shown in Figure 5. From outside to outside of walls, this cesspool chamber occupies exactly 1-6 of the circumference of the entire disposal plant. The inner well forms one wall of the cesspool. The radial walls are each 8 inches thick, made of brick. The outside wall of the cesspool chamber is 8 inches thick instead of 4 inches, as in the case of the remainder of the outside wall. The interior walls of the cesspool chamber must be plastered with a 1 to 2 Portland cement mortar.

The sewage enters the cesspool chamber by a 4 inch vitrified pipe sewer from the house, as shown in figure 5. This pipe ends in a 4 inch elbow which serves as a trap to prevent any escape of gas from the cesspool chamber into the house sewer.

The entering flow is broken up and kept from stirring up the sediment by the wooden device shown in Figure 5. It is important that this device should be constructed exactly as shown in the

figure, for without it the entering current will stir up the sediment in the cesspool chamber, disturb the bacterial agencies of purification, and carry the sediment out upon the sand filter.

The sewage from the cesspool chamber overflows along the entire length of each side wall upon the surface of the upper sand filter. To reach the overflows, the sewage must pass behind baffle-boards, which extend from the roof line down to a point 2 ft. below the entering line of the house sewage, as shown in Figure 5. These baffle-boards must be constructed of 2 in. x 12 in. planking.

After the plant has been in operation some time, the sewage will cover the entire surface of the upper filter, as already described, so that the space between the sand of the upper filter and the under side of the roof will constitute an extension of the cesspool chamber. When this occurs, the effect of any sudden inrush of water will simply be to raise very slightly the level of the sewage. The velocity of outflow from the cesspool chamber will be very slight. Under these conditions, we anticipate a maximum retention of solids in the cesspool chamber.

Ventilator. The ventilator is to be constructed as shown in Figure 5. Except for the 2 in. x 4 in. frames, it is to be made of 1 inch boards. It is hexagonal (six-sided) in shape, just covering the 4 ft. inner brick well. On one side should be placed a 2 ft. x 2 ft. door with 2 in. x 4 in. frame. This door should be hinged and provided with hasp, staple and padlock. It serves to admit entrance to the sewage disposal plant whenever desired.

At the vertex of the pyramidal roof is placed a galvanized iron ventilator, which can be made by any competent tinner. The detailed view of this ventilator is shown in Figure 5 to a large scale. It is 12 inches in diameter at the point where the air enters and 9 inches at the elbow. It is kept pointed in the direction of the wind by a vane composed of a sheet of galvanized iron, as shown in Figure 5. To the interior of the elbow is riveted a socket composed of a piece of 1 inch pipe, 10 inches long. In the upper end of this a piece of double strength glass is fastened by Portland cement, so as to afford an anti-friction bearing on which the ventilator is to turn. It is important that this piece of glass be used, as it is otherwise possible that the ventilator might stick and not turn with the wind. The socket

is upheld by a piece of $\frac{1}{2}$ inch pipe, stayed at the vertex of the roof by iron wires, and supported by a 2 in. x 4 in. foot block, resting on a 2 in. x 4 in. cross brace, all as shown in Figure 5. At the lower part of the galvanized elbow a $1\frac{1}{2}$ inch galvanized iron flange must be formed, as shown in Figure 5, fitting into a wooden slot, also as shown in the figure, to prevent the escape of air.

The object of this ventilator is to insure a current of air through the disposal plant. The vane keeps the ventilator turned toward the wind, whose force will therefore drive a current of air down into the interior of the inner well. After aerating the falling sewage and the drain tile pipes in the under part of the lower filter, this current of air will escape through the five 4 inch vents spaced along the outside wall. This aeration of the sewage in the lower filter is necessary to the successful working of the plant.

BILL OF MATERIAL FOR DESIGN RECOMMENDED

The following is an approximate bill of material for the design of private sewage disposal plant recommended, as shown in Figure 5, and as just described in detail.

We have also added approximate prices, but these will vary in different localities, and each person should ascertain the local prices for himself.

BILL OF MATERIAL

3000 common brick @ \$10.00.....	\$30.00
12 bbl. best Portland cement @ \$2.00.....	24.00
110 rods, $\frac{1}{4}$ in. round x 3 ft. 8 in. }	3.00
55 rods, $\frac{1}{4}$ in. round x 0 ft. 10 in. }	
55 rods, $\frac{1}{4}$ in. round x 0 ft. 4 in. }	9.00
3 pcs. 2 in. x 12 in. x 16 ft. common lumber }	
8 pcs. 2 in. x 4 in. x 12 ft. common lumber }	4.00
10 pcs. 1 in. x 10 in. x 16 ft. common lumber }	
1 pc. 1 in. x 12 in. x 16 ft. common lumber }	.50
1 pr. hinges }	
1 hasp and staple }	3.00
1 padlock }	
1 pc. galvanized screen, 12 in. x 18 in. }	4.00
1 galvanized iron ventilator.....	
6 2 ft. lengths 4 in. vitrified sewer pipe }	76.00
6 4 in. vitrified sewer pipe elbows }	
70 ft. 4 in. drain tile }	73.50
6 cu. yd. sand.....	
11 cu. yd. broken stone or pebbles with all sand screened out, 1/6 inch to 1 inch.....	

\$73.50

Plus cost of sand and pebbles.

SUGGESTIONS FOR CONSTRUCTING PRIVATE SEWAGE DISPOSAL PLANT RECOMMENDED

Two cases present themselves in connection with the construction of a private sewage disposal plant:

First. Where the householder is prepared to do his own hauling and assist personally in the construction of the plant; and

Second, where he must hire everything done.

In the *first case*, where the householder is prepared to do his own hauling and assist personally in the work, the method of procedure of constructing a plant might well be about as follows:

1. Purchase and haul all materials, including galvanized ventilator.

2. Construct the reinforced concrete roof slabs and upper filter floor slabs, using the molds shown in figure 5, using 1 part of cement, to 2 of sand, and 3 of pebbles or broken stone. In the bill of materials enough lumber is provided to construct five molds for roof slabs and five for upper filter floor slabs. The concrete must be thoroughly mixed, and put into the molds in a condition so wet as to flow freely. The reinforcing rods must be put in place the last thing, and must be imbedded just deep enough to be completely covered by the cement so as to be protected from rusting. Of course, the slabs are constructed upside down. They must be left in the molds one day before being taken out, and should then be wet down and covered so as to prevent injury from drying out. To make enough slabs with this number of molds requires six days, but only a part of the time each day need be given to the work. It may be considered preferable to make a larger number of molds, which can be done for a slight added expense for material.

3. While the roof slabs are under construction, make the excavation for the filter plant. This should be about 13 ft. in diameter, so as to leave ample room for the masonry. It should not be made until all the material is on hand nor until it is certain that a mason can be ready to build the brick walls as soon as the excavation is completed.

4. A skilled mason should have been engaged to assist in the construction of the plant, and he should begin work, with the assistance of the householder, as soon as the materials are on hand, the roof and filter floor slabs completed and the excavation made. With the assistance of the householder, this mason then proceeds to build the plant.

5. The outlet tile must be laid and the concrete floor first constructed, using 1 part of cement to 2 parts of sand and 3 parts pebbles or broken stone.

6. The inner and outer brick walls must then be built up to a level ready to receive the floor of the upper filter.

Use 1 part cement to 3 parts sand for the mortar for all brick work.

Note: Be careful to keep the true circular shape so that the reinforced concrete slabs may fit. Be sure to omit every other half brick at lower filter floor level, and to leave projecting brick to carry two plank over sedimentation basin. Be sure to put in place the wooden baffle-boards and current breaking device in the cess-pool chamber. Be sure to construct rectangular openings from the inner well to the space between the lower and upper filters, and to set in place in the outer brick wall the vitrified elbows for the five air vents.

7. The pebbles for the lower filter must be put in place.

8. The reinforced concrete slabs forming the floor of the upper filter must be put in place.

9. The construction of the upper part of the brick walls must be completed.

Note: Be sure to make the junction of these walls with the floor of the upper filter water-tight, and to plaster with 1 to 2 cement mortar the brick walls of the upper filter and of the cess-pool chamber, as indicated in Figure 5.

Set in place in the brickwork of the cesspool chamber the inlet sewer, and complete the wooden device for breaking up the current, as shown in Figure 5. Note that the baffle-boards in the cesspool chamber extend clear up to the roof line, and must be cut to the right slope.

10. Construct the six-sided wooden ventilator as shown in Figure 5. The galvanized iron ventilator should have been se-

cured from a good tinner in advance of beginning the construction.

Note: The wooden ventilator must be neatly painted on final completion of the work.

11. Put in place the sand of the upper filter. Be sure to fill the slots in the floor of this filter with very small pebbles and take especial pains to see that the upper portion of the slots is filled with pebbles small enough to hold up the sand of the upper filter. When the sand of the upper filter is in place, pour water all over it to make sure that the sand will not wash down through the pebbles in the slots. It is very important that this test be made thoroughly, and any defects remedied before the sewage is turned in.

12. Complete the five 4 in. air vents around the outside of the tank.

13. Put the roof slabs in place.

14. Thoroughly clean out the inner well and all other portions of the disposal plant. Place the plank platform over the sedimentation basin.

15. Complete the outlet from the disposal plant to the point of final discharge, and the inlet sewer from the house to the disposal plant.

In the *second case*, where the householder must hire everything done, he may proceed as in the first case, hiring teams and men to do the hauling and excavating and other labor which he cannot perform himself. A second method would be to award a contract to a skilled workmen to build the entire plant, the householder furnishing the materials. A third method would be to award a contract for the entire plant, the builder to furnish all the materials. The second of the above methods will often be found preferable, but local conditions must determine the method used.

INSTRUCTIONS FOR OPERATING THE PRIVATE SEWAGE DISPOSAL PLANT

The householder is advised to examine his sewage disposal plant from time to time making sure that it is operating satisfactorily.

About once a year, most of the contents of the cess-pool chamber should be pumped out. The sediment found therein can be

plowed under in any garden or disposed of in the same way as other manure. It will be found to have decomposed to such an extent as not to be very offensive to handle. If a pump is not available, the contents of the cess-pool chamber may be dipped out with a pail. Only the bulk of the sediment need be removed. While it is believed that this should be done once a year, yet a roof slab may be removed and the depth of the sediment tested with a sounding rod. If little or no sediment is found, this cleaning out will not be necessary.

In a similar way, the sedimentation basin at the bottom of the inner well should be pumped or dipped out whenever the sediment accumulates to any considerable extent. Unless examination should show the absence of sediment, it is advised that this cleaning out should be done once a year.

As already stated, there is danger that the sand of the upper filter might break down through the supporting pebbles in the slots of the filter floor unless these have been carefully placed. Examination should be made from time to time, especially until the sewage has entirely covered the upper filter to a depth of several inches, to make sure that such breaking through has not occurred. Any breaks which do occur must be remedied at once.

At intervals which cannot be foretold, but which it is considered probable will not be oftener than once in two years, it will be necessary to take out the sand of the upper filter and replace it with clean material. About one load of material will be necessary.

CAUTION CONCERNING PATENTS.

Patents have been issued in the United States and England on the septic process of purifying sewage, and the validity of the U. S. patent, so far as it relates to the general process, has been upheld in the United States Circuit Court of Appeals for the district in which the State of New York is located. It is claimed that these patents expired in November, 1909, but this is denied by the owners of the patents. While the authors of this bulletin believe that the cess-pool chamber forming a part of the sewage disposal plant recommended is, scientifically, simply a cess-pool such as has been constructed from time im-

memorial, though slightly modified in this case, yet we do not guarantee that the holders of the septic process patent may not claim infringement of their patent by the design shown. Any persons building the private disposal plant recommended, must do so entirely upon their own responsibility.

BLUEPRINT PLANS OF THE SEWAGE DISPOSAL PLANT FOR PRIVATE
HOUSES CAN BE OBTAINED FROM THE ENGINEERING
EXPERIMENT STATION, AMES, IOWA.

We shall be pleased to send out free of charge, a blueprint plan of the sewage disposal plant described in this bulletin to anyone who will write for the same to A. Marston, Director, Ames, Iowa, and who will make a statement that he proposes to build the plant. Copies of this bulletin can be obtained in the same way.





